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DAMPNESS IN MASONRY WALLS ABOVE GRADE[1/]

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1/ Methods of waterproofing walls below grade are discussed in the following publications:

Farmers' Bulletin No. 1572, "Making cellars dry." May be consulted in Government depository libraries, or copies obtained from the Superintendent of Documents, Washington, D. C. at 5 cents each.

"Waterproofing engineering," By Joseph Ross; "Concrete building construction," By Crane and Nolan, both published by John Wiley and Sons, New York, N. Y.

I. Introduction

Inquiries received at this Bureau on the subject of damp masonry indicate that no type of masonry is entirely free from this defect. Reports of individual instances indicate that improper design or faulty construction may have accounted for the dampness. Although most types of masonry units and jointing materials are permeable, the amount of moisture transmitted through the pores is usually too small to cause damage to interiors.

Studies[2/] on the permeability of certain masonry materials

[2/] N.B.S. RP 394, "Tests of integral and surface waterproofings for concrete,"

Tech. Paper No. 305, "Permeability of stone,"

Tech. Paper No. 3, "Tests of the absorptive and permeable properties of portland cement mortars and concretes."

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have been made at this Bureau and measurements of the rain resistance of masonry walls are in progress. The following discussion is based on these investigations and the results of observations in an effort to supply more complete information than can be feasibly done by individual replies to inquiries.

II. Causes of Dampness

a. Penetration of rain water

Dampness on interior surfaces of walls may be caused by rain water blown against the walls or by water collected on roofs or other horizontal surfaces entering the masonry and reaching the interior, sometimes at a considerable distance below the place of entry.

Structural defects which permit the drainage water to flow onto or into the masonry are believed to be the most common causes of dampness in masonry walls. The nature of the defects is well known, but in order to avoid them it is necessary for the designer to make plans for conveying rain water away from the masonry and for the builder to carry out the details with care.

The likelihood of rain entering through exposed vertical faces of walls in sufficient amounts to cause dampness on interior surfaces is largely dependent upon wind velocity, intensity and duration of rainfall, and the location of objects tending to shield the wall as well as upon the permeability of the walls.

In some localities rainfall accompanied by wind of sufficient intensities to cause the saturation of masonry walls may be expected many times during the life of a building. For example, in states bordering on the Atlantic Ocean, rains lasting over a period of three days with an average rainfall of 0.05 in. per hour are not uncommon. During such a rain 3.6 in. would fall on a horizontal surface. The intensity of the rainfall on a vertical surface would be about twice as much with a wind velocity of 10 miles per hour and about three times as much with a velocity of 20 miles per hour. The amount of water required to saturate a 12 in. wall of solid brickwork ranges from approximately 0.15 to 6.0 in., considering the water to be spread uniformly over the exposed face of the wall. Most brickwork has a capacity ranging from 1 to 4 in. in the same unit. It is obvious, therefore, that rains of the intensity assumed above, when accompanied by winds having an average velocity of 6 miles per hour or more, would cause the complete saturation of the wall if all of the water were absorbed. The results of laboratory tests of masonry walls exposed under conditions simulating that produced by wind-driven rains indicated, however, that penetration by capillarity alone was a slow process. For example, only the most rapidly absorbing brick were wetted through from end to end within a period of 1 hour, most bricks requiring several hours and some several days. Similarly moisture was transmitted very slowly by capillarity through mortar joints, the time required for water to penetrate solid mortar joints in an 8 in. wall generally being more than 1 day. Walls of bricks of extremely low absorption with well-filled mortar joints did not transmit moisture during an exposure of 2 weeks. Other walls of similar materials but with poorly filled joints leaked in periods ranging from 2 to 5 minutes. It is obvious, therefore, that excessive rain penetration in masonry walls results from openings in the joints rather than from capillary transmission of moisture through the masonry materials.

b. <u>Condensation moisture</u>

Atmospheric moisture condenses on or in a wall whenever its temperature is less than the dew-point temperature of the adjacent air. The amount of moisture deposited will depend mainly on the temperatures of the wall and air, the relative

humidity of the air, and the volume of the air which moves over the surface. The dew-point temperature depends chiefly on the temperature and relative humidity of the air. Minimum differences between the temperatures of the air (T_a) and of the wall (T_w) at various relative humidities to cause condensation are approximately as follows:

Relative humidity of the air	$T_a - T_w$
%	°F
30	33
50	20
70	10
90	3

Condensation, particularly on massive masonry walls, sometimes occurs during periods in which the temperature of the air is rising rapidly. Because of the large heat capacity of the masonry, the temperature of the wall tends to lag behind that of the air, and if the relative humidity of the air is abnormally high a temperature difference may be reached which will cause condensation. Likewise condensation sometimes occurs in buildings which are heated intermittently during cold weather. During cold weather condensation may take place on the interior surfaces of the outer walls because of an insufficient amount of thermal insulation. This is most apt to occur in kitchens, bathrooms and laundries where the relative humidity of the air is often high.

Because the relative humidity of air inside of dwellings is generally very low while heating plants are in operation, dampness from condensation during cold weather is not common. However, when humidifying devices are used, wall insulation usually is needed if outdoor temperatures are less than 30°F. The thermal insulation provided by furring alone is not an adequate safeguard when temperatures as low as 10°F occur unless the relative humidity is maintained at less than 60 percent. Estimates of the amount of insulation required can be made by engineers familiar with the wall construction and the operation of the air-conditioning equipment.

When walls become damp during rainy weather only, it is not always apparent whether the source of moisture is condensation from the air or from rain water passing through the wall. To answer this question a simple test may be made by cementing a thin piece of metal having a polished surface, or a mirrored glass, onto the face of the wall. If no moisture collects on the surface it may be concluded that condensation is not the cause of dampness. If moisture collects on the surface condensation may be considered as either the sole cause or only a contributing factor. Condensation within the

wall structure may occur and may result in the deposition of a sufficient amount of moisture to cause dampness on interior surfaces if the permeability to air of the warmer surface is greater than that of the colder surface and the temperatures within the wall are below the dew-point temperature of the warmer air.

In interpreting the results of such tests, it should be borne in mind that moisture may condense on a wall surface without causing noticeable dampness on the interior if the wall absorbs the moisture as rapidly as it is deposited. Although the wall surface does not appear to be damp, the condensation of moisture may have a deleterious effect on the plaster or decorations.

c. Capillary rise of ground water

Moisture rising from the ground is not a frequent cause of dampness in walls above grade. Where soil drainage is not adequate and the foundations of walls have not been suitably waterproofed, a sufficient amount of moisture may be drawn up by capillarity to cause dampness in the walls some distance above ground level. Measurements of capillary forces in masonry materials at this Bureau indicate that some materials can draw moisture to a height of 20 feet but that for most types of masonry the height would not be greater than 5 or 6 feet.

A test that can be applied as an indicator of capillary moisture may be made as follows: Support a glass crystallizing dish containing a small amount of dry calcium chloride on a temporary shelf and seal it to the interior surface of the wall with wax or a plastic caulking compound. Preferably two such tests should be made, one near the first floor level and another near the top of the damp area. If the calcium chloride gradually melts down to a liquid during a period of dry weather, the indication is that moisture is rising from the ground. The calcium chloride in the lower dish should melt considerably faster than the one at the higher level. The test should extend over a period of several days.

III. Preventive Measures

a. Penetration of rain water

1. Water entering through horizontal surfaces.--All horizontal or sloping surfaces, unless continuous and nearly impervious, should be either waterproofed or separated from the masonry below by flashing of durable materials. For example, copper flashing may be provided under copings, cornices, pervious or jointed sills, and projecting courses of masonry. Metal caps spaced a few inches above chimney vents are desirable. In

furred wall construction flashing should be installed at the tops of window frames and wherever members join the plaster with the masonry, in order to divert water from the inner face of the masonry to the outside. At junctions between parapet walls and roofs, the flashing which is built into the roof surfacing should be extended upward high enough to prevent overtopping by roof water and then through the wall to within one inch of the outer surface. Construction which projects beyond the exposed vertical faces of walls should be provided with undercut drips, in order to shed the water away from the walls.

Where flashings have not been used as suggested above, defective joints in copings and cornices should be filled with mortar or preferably with a plastic caulking compound. If such parts are built of materials which absorb readily, two or more coats of a colorless liquid waterproofing should be applied to the entire surface.

2. <u>Water entering through vertical surfaces.</u>--The possibility of dampness penetrating through vertical walls should be taken into consideration in the original plans and specifications. In order to obtain well-filled joints and a complete contact of mortar with the masonry units, it is essential that the mason use a mortar of good working properties. With units which absorb water rapidly, it is preferable to use mortars which offer a considerable resistance to loss of moisture when in contact with absorbent units. Masonry units which absorb water rapidly should be damp when laid. The amount of water in the unit preferably should be such that, when one face is in contact with water, the absorption during the first minute will be between 0.06 and 0.4 lb per sq ft of contact area (approximately 0.03 to 0.2 g per sq cm).

Repairs to flashings and waterproofing of horizontal surfaces should always precede the application of waterproofing treatments to vertical surfaces. Openings in joints around window frames or where the masonry joins other materials should be filled, preferably with a plastic caulking compound. As open spaces large enough to be seen cannot be sealed with a colorless waterproofing, these should be filled and the joints in the masonry should be repointed where there is doubt about their tightness. Vertical joints (head joints) are more often defective than are horizontal joints. If the facing bricks are of smooth texture the defective joints may be sealed by scrubbing the exposed face of the joints with a grout of portland cement and fine sand. A small stiff fiber brush should be used. Before using the grout the masonry should be thoroughly wetted. A grout, consisting of 1 part cement to 1 part of fine sand by volume, with sufficient water to give a consistency

of thick cream or soft butter, should be scrubbed into the openings in the joints, removing the excess on the surface. Bricks stained by the treatment may be cleaned before the cement has hardened by mopping with a damp sponge. The foregoing repairs may prevent dampness on interiors without the use of a pore-sealing treatment on exterior of vertical surfaces.

Where it is known that water passes through the masonry units and causes damp interiors, one may resort to a colorless liquid waterproofing treatment. They are effective in sealing the pores in the masonry materials but do not seal cracks or other relatively large openings in the joints. Wherever such treatments are used the entire exterior of the building should be sealed. If water can enter at any point and penetrate behind the waterproofing it will have to escape through the interior surface. If, for instance, a wall of rapidly absorbing brick were treated to the top floor level and the parapet wall left unsealed, water could enter and percolate downward back of the treated face. Under such conditions dampness on the interior would probably be increased and efflorescence on the exterior may result.

There are several types of such waterproofings on the market, the majority of which fall under the following classification: (1) metallic salts of fatty acids (aluminum stearates and oleates) dissolved in mineral spirits or other suitable solvent, (2) waxes dissolved in mineral spirits, (3) waxes applied in a molten state, (4) thinned oils alone or with waxes in solution, and (5) thinned varnishes.

A study of such waterproofings by means of exposure tests[3/]

[3/] N.B.S. RP 771, "Experiments on exterior waterproofing materials for masonry."

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has indicated that materials under the first classification are effective in waterproofing most types of masonry, but when exposed to the weather they deteriorate within two or three years. When properly applied, this type has the advantage of being free of discoloration effects on all types of masonry, but a few cases have come to our attention where this treatment has apparently caused efflorescence. Materials under the second classification usually discolor masonry more or less, but they are superior in durability. When the wax used is a good grade of high melting point paraffin, the treatment should be effective for 10 years or longer. The molten wax type usually consists of a high melting point paraffin and the seal is somewhat better than that obtained with paraffin solutions. The treatment is rather

expensive as it requires special equipment and skilled workmen for its application. Materials under the fourth classification discolor considerably and are not as durable as the wax treatments. Thinned varnishes discolor most types of masonry considerably and usually leave a film on the surface which is especially noticeable on dense masonry units.

A paraffin waterproofing solution can be made at small cost by dissolving about 3/4 lb of paraffin (melting point 135°F or higher) to the gallon of mineral spirits, naphtha, gasoline, or other organic solvent. The solution is easily obtained at a temperature of 70°F or higher by shaving the wax into the solvent and stirring. It may also be made by melting the wax and pouring it into the solvent, but when the more volatile solvents like gasoline are used, care must be taken not to bring either the solvent or the solution near an open flame. While this solution gives high waterproofing values and quite satisfactory durability on most masonry materials, it has been found that certain materials with very fine pore spaces cannot be entirely sealed with this preparation. In treating such masonry materials one can obtain better results by adding about 6 or 7 ounces of raw chinawood oil to each gallon of the paraffin solution, as described above. The masonry should be thoroughly dry and the waterproofing should not be applied when the wall temperature is below 70°F. Two coats are usually required and the first should be allowed to dry for 24 hours or more before the second is applied. Liberal amounts should be used but it is not necessary to saturate the wall with the first treatment. However, the second application should be continued until the masonry no longer absorbs the solution rapidly.

Waterproofing (usually bituminous) is sometimes applied to the inner faces of walls. There is some doubt regarding the value of such waterproofing. Reports of experience indicate that many walls so treated had become damp during heavy rains and with some of these the waterproofing had blistered. Both the results of laboratory tests and of experience with structures indicate that treatments consisting essentially of thinned bituminous solutions are not effective. Relatively thick applications of hot tar or asphalt or trowelled coatings of asphalt mastic are highly resistant to moisture but may blister when water penetrates to the surface on which they are applied. Another obvious defect of waterproofing by means of interior treatments is the common practice of omitting the coatings opposite the ends of floor joists and slabs, where the thickness of the masonry normally is considerably less than elsewhere.

b. Condensation moisture

To avoid condensation during cold weather on the interior of inclosure walls, sufficient thermal insulation should be provided to prevent the temperature of the interior surfaces from falling below the dew-point temperature of the air. For dwellings in which the air is not humidified artificially the amount of insulation required is not large. An air space, sheets of insulating material such as corkboard, rock wool or a fibrous or mineral insulation board 1/2 in. or more in thickness should suffice. If the insulation is provided by furring, the width of the air space should be about 3/4 in., because, for narrower spaces, the insulating value is low and for wider spaces it is not much greater. The installation of insulation may not prevent condensation within the wall if the temperature in the interior is below the dew-point temperature of the warmer air and the air permeability of the warmer side is less than that of the cooler side.

If the humidity of the air in a building is unusually high (as is likely in laundries and some buildings used for manufacturing), ventilation will be an aid in preventing dampness from condensation. To prevent the deposition of moisture within walls of such buildings it would be desirable to have an interior finish of a material much less permeable to air than the wall materials.

c. Capillary rise of ground moisture

To prevent dampness from capillary moisture from the ground, dampproofing courses should be extended entirely through the wall at a height of 5 to 10 inches above the surface of the ground. These courses may consist of layers of impervious materials, such as slate or sheet copper. As an optional method, mortar containing a water repellent may be used for three or more courses of the masonry above grade. Cements in which the water repellent is incorporated are generally available, or the repellent ingredients may be purchased in the form of pastes or powders and incorporated in the mortar. These materials usually consist of salts of fatty acids, such as stearates or oleates of ammonium, sodium, or calcium. The sodium and ammonium salts are found on the market in the form of pastes, while the calcium type may be obtained as a dry powder, usually consisting of hydrated lime and calcium stearate. The amount of such admixture used should provide a fatty acid content equal to from 0.1 to 0.2 percent of the weight of the cementing materials. The producers' specifications usually give the amounts of their admixtures to use, which is ordinarily about 2 percent of the weight of the cement-

ing materials. The pastes are added to the mixing water, but the dry powders are mixed with the sand and cement before water is added.

For stone masonry, especially of limestone and sandstone, it is considered good practice to use a granite base or at least one course of granite extending through the wall and slightly above the ground line. Such grade courses should be bedded and jointed in a dampproofed mortar as described above.